REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
10-09-2010

2. REPORT TYPE
Technical Paper

3. DATES COVERED *(From - To)*
SEPT 2010 - OCT 2010

4. TITLE AND SUBTITLE
Method and Apparatus for Short-Term Prediction of Convective Weather

5a. CONTRACT NUMBER
FA8720-05-C-0002

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Marilyn Wolfson and Megan H. Blackwell

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
MIT Lincoln Laboratory
244 Wood Street
Lexington, MA 02420

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Federal Aviation Administration
800 Independence Avenue, SW
ATO-P
Washington, DC 20591

10. SPONSOR/MONITOR'S ACRONYM(S)
FAA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: U			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Zach Sweet
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
U	U	U	SAR	3	781-981-5997

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

JA-6EN-7223

Method and Apparatus for Short-Term Prediction of Convective Weather

This patent describes the work of nine New England inventors on a convective weather forecast algorithm. One implementation of the method is a multiscale storm-tracking algorithm that internally determines the type and strength of existing storms—their motion, their growth and decay trends, and the locations of new storm initiation—and forecasts their evolution on the basis of models developed from thunderstorm case studies. This technique is a breakthrough in forecasting because it

- Integrates detected precipitation in a vertical plane to provide a clear two-dimensional indication of storm severity
- Tracks large- and small-scale features within a storm complex

and

- Includes explicit detection of storm growth and decay

Versions of this algorithm are currently being used in the Integrated Terminal Weather System (ITWS) and the Corridor Integrated Weather System (CIWS)—two main weather forecasting systems whose products are used by operational air traffic management of the Federal Aviation Administration (FAA). Some of this forecast technology is also being used in the National Convective Weather Forecast run at the Aviation Weather Center, in the National Center for Atmospheric Research Auto-nowcaster, and in various private-vendor forecast systems.

The ability to provide accurate weather forecasts to air traffic managers and controllers plays a very important role in assuring that the nation's airliner flights will remain safe and on schedule. Strategic air traffic planning takes place daily in the National Airspace System and two-to-six-hour forecasts are utilized, but these early plans remain unaltered in only the most predictable of convective weather scenarios. More typically, traffic flow managers and airline dispatchers help flights to utilize jet routes that remain available within regions of convection, or facilitate major reroutes around convection, according to the available playbook routes. For this tactical routing in the presence of convective weather to work, the FAA recognized that both a precise and a timely shared picture of current weather is required, as well as an accurate, reliable, short-term zero-to-two-hour forecast. Such forecasts help reduce the system-wide and airport-specific delays that are so prevalent in the summer months. This is especially important as the economy grows, traffic demands approach full capacity at the pacing airports, and more jets, including regional jets, seek to utilize the same en route jetways.

Theory of Operation

Precipitation as detected by radar is integrated in the vertical plane. The weather classification scheme extracts lines, cells, and stratiform precipitation regions from the images of vertically integrated liquid water (VIL) and is used to assign specific phenomenological behavior in subsequent forecast evolution models. Figure 1 shows an example of a simplified classification algorithm and sample images. Functional template correlation techniques and image processing region analysis are used to extract weather features that are then applied to sort the pixels into specific categories. This approach not only classifies the radar returns as convective or non-convective but also assigns them a distinct phenomenological class.

This work is sponsored by the Department of the Air Force under Air Force Contract #FA8721-05-C-0002. Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed

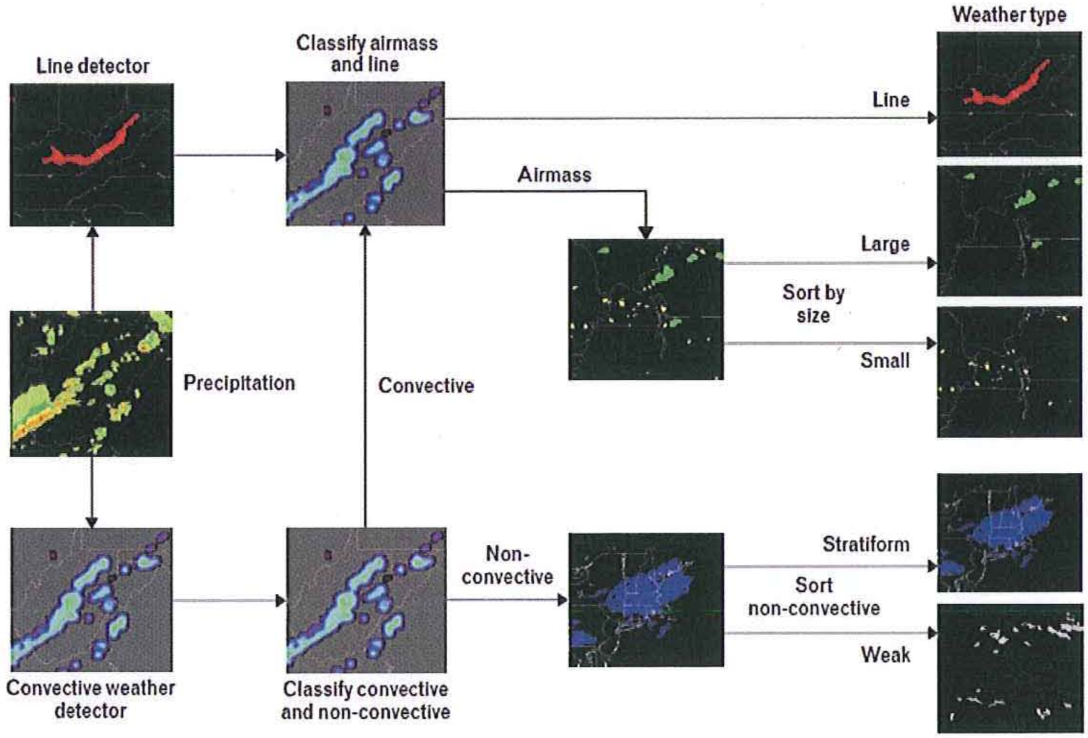

Figure 1: A simplified flow diagram for a weather-prediction algorithm. Steps include fundamental line- and convective-weather interest detections using functional template correlation and region analysis, secondary interest detections using thresholding and region size sorting on convective and non-convective elements, and a rule-based precedence ordering where the primitive images are used to assemble the final weather classification image.

Both large- and small-scale tracking configurations are used to process each radar data set. The small-scale vectors better capture the motions of individual cells within a storm complex, while the large-scale vectors better capture the motions of the entire storm structure. A cross-correlation tracking method is employed to obtain the speed and direction of storm cells and storm envelopes.

A growth and decay trends algorithm consists of a large suite of image processing feature detectors that produce interest images used in the forecast combination. An important image-processing step for several of the feature detectors is the differencing of two VIL or two echo tops images, as shown in Figure 2. The movement of the precipitation over time is conveyed from the prior image to the current time with a set of vectors that capture the desired scale of motions. The cell vectors are used for the short-term trend image, while the envelope vectors are used for the long-term trend image. Once the prior image is aligned in time with the current image, the two images are subtracted. This difference image represents the change in VIL or echo tops over the given time period.

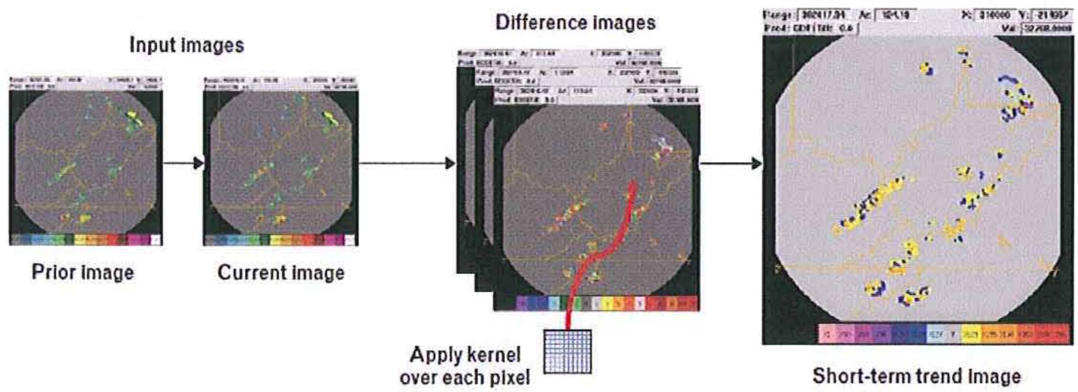

Figure 2: Trending of vertically integrated liquid (VIL) precipitation and echo top heights is done by conveying the movement of precipitation from previous images to the current time and computing the difference. Two or more difference images are averaged to produce the averaged difference image. A series of detectors are then applied to produce the growth and decay trends interest image. The images shown are echo-tops trends.

Operational Impact

The products developed using the above-described techniques have been deployed operationally as part of the FAA CIWS and ITWS systems and have proven extremely useful to both terminal and en route traffic management. The first ITWS with the terminal convective weather forecast capability was deployed in New York in the summer of 2006. One of its biggest benefits to passengers is safely keeping jet routes open longer. This capability alone was anticipated to provide $89 M per year in benefits on the basis of prior CIWS usage. By knowing with high precision where the storms are (NEXRAD precipitation) and how tall they are (echo tops), where and how high those storms are forecast to be in the near future (precipitation forecast and echo tops forecast), and where the storms are actively growing (growth and decay trends), en route traffic managers have the confidence to allow as much of the heavy traffic in the congested northeast corridor as possible to keep running, and to make their destinations safely and on time. And that is something we, the flying public, can all appreciate!